IPSR (Integrated Photonic Systems Road mapping) Group
iNEMI-IPSR Board-Level Optical Interconnect Project

Project Leader: Tom Marrapode, Molex
iNEMI Staff: David Godlewski, Bob Pfahl

June 13-14, 2018

Recording (available for up to 6 months after webinar):
https://inemi.webex.com/inemi/ldr.php?RCID=5ba8dd96b378aced3880e8ac3de2d08b
Need Being Addressed:

- The assessment of the performance of prototypes of board-level interconnect systems based on single-mode (SM) fiber, expanded-beam optical coupling, and silicon photonics transceivers. This activity will allow evaluation of existing and developing components, and thereby will identify gaps in the board-level technologies needed for practical implementation.

Proposed Solution:

- This need was one of three identified in the 2016 Roadmap as being critical to the widespread implementation of board level integrated photonic systems. The team has met weekly this fall to develop this self-funded project to address the need.

Funding

- This project is self-funded by the industrial participants

Constraints:

- This solution is dependent on all participants honoring the commitments they have made to the project
- Participants will be required to sign a statement of work (SOW) and IP Agreement.

Timeline:

- One Year (2017)
Specific Component and System Characterizations

- Connector loss
- Wavelength dependence of connector loss
- Connector return loss
- Connector polarization-dependent loss
- Connector re-mating loss variation
- Signal Bit Error Rate vs. connector number and loss (up to 25 Gbps/channel)

Additional Proposed Testing:
- Dust contamination induced connector loss (Test TBD)
- Environment Thermal Aging, Humidity Aging, Thermal Cycling, and Humidity/Condensation Cycling testing
# Participants

<table>
<thead>
<tr>
<th>Affiliation</th>
<th>Participant</th>
<th>Title</th>
<th>Proposed Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molex</td>
<td>Tom Marrapode, IPSR Project Leader</td>
<td>Director of Advanced Technology Development</td>
<td>Interconnects; backplane, front panel, I/O and cables</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Prototype single mode expanded beam MT ferrules</td>
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<tr>
<td>Celestica</td>
<td>Tatiana Berdinskikh</td>
<td>Principal Optical Engineer</td>
<td>Rack Hardware</td>
</tr>
<tr>
<td>Juniper Networks</td>
<td>Valery Kugel</td>
<td>Distinguished Engineer</td>
<td>Link test parameters and performance evaluation</td>
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<td></td>
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<td>In house testing</td>
</tr>
<tr>
<td>US Conec</td>
<td>Darrel Childers, Sharon Lutz</td>
<td>Director of Development Product Manager</td>
<td>Prototype single mode expanded beam MT ferrules</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interconnects; backplane, front panel, I/O</td>
</tr>
<tr>
<td>3M Company</td>
<td>Terry Smith</td>
<td>Senior Staff Scientist</td>
<td>Organizer-Planning for next phases</td>
</tr>
<tr>
<td>US Competitors</td>
<td>John Mac Williams</td>
<td>Principle</td>
<td>Advisor-Planning for next phases</td>
</tr>
<tr>
<td>MIT</td>
<td>Kazumi Wada</td>
<td>Professor</td>
<td>Advisor-Planning for next phases</td>
</tr>
<tr>
<td>Senko</td>
<td>Tiger Ninomiya</td>
<td>Business Development</td>
<td>Prototype expanded core fiber MT</td>
</tr>
<tr>
<td>Fraunhofer</td>
<td>Dr. Henning Schröder</td>
<td>Group Leader Optical Interconnection</td>
<td>Observer for next phases</td>
</tr>
<tr>
<td>IPSR</td>
<td>Robert Pfahl</td>
<td>Director of Roadmapping</td>
<td>Facilitator-Planning for next phases</td>
</tr>
<tr>
<td>iNEMI</td>
<td>Dave Godlewski</td>
<td>Manager of Deployment</td>
<td>Project Facilitator</td>
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</tbody>
</table>
Proposed Demonstrator Interface Juniper, Molex / Senko

- 3 SM Fiber Expanded Beam MT Ferrules (add links by looping)
- Front Panel I/O 1x3 Circular MT Connector
- Line Card
- Parallel SiPh Transceiver
- HBMT® Backplane Connector
- SM Fiber Cables (add links by looping)
- 4 SM Fiber Expanded Beam MT Ferrules
- Driver and Measurement Instrument

HBMT is a registered trade mark of Molex LLC
Proposed Demonstrator Interface, Juniper, USCONEC

1 SM Fiber Expanded Beam MT Ferrules

Front Panel I/O MXC Adaptor

SM Fiber Cables

6 SM Fiber Expanded Beam MT Ferrules (add links by looping)

Line Card

Backplane

Parallel SiPh Transceiver

Driver and Measurement Instrument

MXC® Backplane Connector

MXC is a registered trade mark of US Conec Ltd.
Optical Cabling Detail View

- SM Fiber Expanded Beam MT Ferrules
- Front Panel I/O Adaptor Body
- SiPh TRX
- IL/RL Test Set
- SM Expanded Beam MT Ferrule
- MTP®-PRO (allows male/female and key change)

Connections:
- L=1M
- L=3M
- L=3M loop back
- Backplane Connector Body 4 or 6 mated ferrules
- SM Fiber Expanded Beam MT Ferrules (add links by looping)
- MTP-PRO (allows male/female and key change)

- SM Fiber Cables
- Add links by looping

MTP is a registered trade mark of US Conec Ltd.
ATCA Standards Based Chassis

Zone 3 Open
Zone 2 Signal
Zone 1 Power

Zone 3 Open
Zone 2 Signal
Zone 1 Power
ATCA Chassis

Front View

Back View
ATCA Chassis

HBMT Inside View

MXC Inside View
Testing Link Explanation

Mated Pair 1
EXB A / EXB B

Each half of an expanded beam connector (EXB) = one mated pair

3 EXB connectors = 3 mated pair

5 EXB connectors = 5 mated pairs
IL/RL Setup

- Based on JDSU MAP-200 with integrating sphere, 2 24x optical switches. Bi-directional IL/integral RL measurements at 1310/1490/1550/1625nm.

Test set allows bi-directional measurements allowing for reversal of optical signal. All reported data includes both measurements.

RL is measured using integration method (integral of reflected signal 1m from MTP connectors on both sides of the DUT).

FC/APC to FC/APC are 5m cables; FC/APC to 1x12 MT are 3m cables.
Silicon Photonic Module  8x25G Setup

Avago Test Board with 25G Tx/Rx

8x25Tx

SiPh
8x25G on-board engine

8x25Rx

MTP 0
female MTP Tx

124487
124488
124527
124528

MTP 1
Male MTP Rx

To Vendor DUT

USConec reference assembly with 1x12 SMF MT Elite ferrules

Note: when measured in a loopback (MTP Tx is directly mated to MTP Rx), opposed key MPO adapter is used. This is because the end MT ferrules are flipped in USConec reference assembly compared to a standard setup.
Insertion Loss Vendor: A 1 mated Pairs, Includes All Measurement Data (1310-1625nm & 3 Mate/Demates, Fwd/Rev)

Insertion Loss (-)

Channel 3  Channel 4  Channel 5  Channel 6  Channel 7  Channel 8  Channel 9  Channel 10

Driving Photonics Manufacturing
Return Loss Vendor: A
1 mated Pairs, Includes All Measurement Data
(1310-1625nm & 3 Mate/Demates, Fwd/Rev)
Insertion Loss Vendor: A
5 mated Pairs, Includes All Measurement Data
(1310-1625nm & 3 Mate/Demates, Fwd/Rev)
Return Loss Vendor A
5 mated Pairs Includes All Measurement Data
(1310-1625nm & 3 Mate/Demates, Fwd/Rev)
Insertion Loss Vendor: B
4 mated Pairs, Includes All Measurement Data
(1310-1550nm & 6 Mate/Demates, Fwd/Rev)
Return Loss Vendor: B
4 mated Pairs, Includes All Measurement Data
(1310-1550nm & 6 Mate/Demates, Fwd/Rev)
Insertion Loss Vendor: B
1 mated Pairs, Includes All Measurement Data
(1310-1550nm & 6 Mate/Demates, Fwd/Rev)
Return Loss Vendor: B
1 mated Pairs, Includes All Measurement Data (1310-1550nm & 6 Mate/Demates, Fwd/Rev)
# Silicon Photonics Link Testing Results

<table>
<thead>
<tr>
<th>Module channel</th>
<th>TX Power dBm</th>
<th>Rx Power dBm</th>
<th>Lens IL @Module dB</th>
<th>Lens IL Test set dB</th>
<th>Lens RL Test set dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-2.80</td>
<td>-2.05</td>
<td>-2.80</td>
<td>-2.60</td>
<td>0.55</td>
</tr>
<tr>
<td>1</td>
<td>-2.85</td>
<td>-1.90</td>
<td>-2.85</td>
<td>-2.50</td>
<td>0.60</td>
</tr>
<tr>
<td>2</td>
<td>-2.80</td>
<td>-2.10</td>
<td>-2.80</td>
<td>-3.05</td>
<td>0.95</td>
</tr>
<tr>
<td>3</td>
<td>-2.65</td>
<td>-2.05</td>
<td>-2.65</td>
<td>-2.50</td>
<td>0.45</td>
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<tr>
<td>4</td>
<td>-3.10</td>
<td>-2.70</td>
<td>-3.10</td>
<td>-3.10</td>
<td>0.40</td>
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<tr>
<td>5</td>
<td>-2.70</td>
<td>-2.20</td>
<td>-2.70</td>
<td>-2.75</td>
<td>0.55</td>
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<tr>
<td>6</td>
<td>-2.60</td>
<td>-2.10</td>
<td>-2.60</td>
<td>-2.60</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>-2.85</td>
<td>-2.60</td>
<td>-2.80</td>
<td>-3.25</td>
<td>0.65</td>
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</tbody>
</table>

*25.78125Gbps, PRBS31; Avago SerDes are tuned at loopback measurements, BER is measured at Avago board, optical power - at SiPH engine SW
## Detail Schedule

<table>
<thead>
<tr>
<th>Task</th>
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<tbody>
<tr>
<td>Project scoping</td>
</tr>
<tr>
<td>Mechanical layout of cards and backplane for connector housing attach</td>
</tr>
<tr>
<td>Machine/modify cards and backplane for connectors</td>
</tr>
<tr>
<td>Assemble connector components onto card and backplane</td>
</tr>
<tr>
<td>Test mechanical function</td>
</tr>
<tr>
<td>Debug</td>
</tr>
<tr>
<td>Build Optical cables</td>
</tr>
<tr>
<td>Ship to test locations</td>
</tr>
<tr>
<td>JUNIPER Site Testing</td>
</tr>
<tr>
<td>Assemble test units</td>
</tr>
<tr>
<td>Debug</td>
</tr>
<tr>
<td>Pre-test to verify good links</td>
</tr>
<tr>
<td>Debug</td>
</tr>
<tr>
<td>Standard test set IL/RL 1310-1625nm baseline data for MT connections</td>
</tr>
<tr>
<td>Standard test set IL/RL 1310-1625nm baseline data for EXB connections (Vendor A)</td>
</tr>
<tr>
<td>Standard test set IL/RL 1310-1625nm baseline data for EXB connections (Vendor B)</td>
</tr>
<tr>
<td>Standard test set IL/RL 1310-1625nm baseline data for EXB connections (Vendor C)</td>
</tr>
<tr>
<td>25G BER test one mated pair (Vendor A)</td>
</tr>
<tr>
<td>25G BER test one mated pair (Vendor B)</td>
</tr>
<tr>
<td>25G BER test one mated pair (Vendor C)</td>
</tr>
<tr>
<td>Temperature test RT to 70C 5 Cycles (how many mated pairs)</td>
</tr>
<tr>
<td>10G BER test one mated pair. (BER of the total link, eye diagram (PRBS31), Tx/Rx optical power, ER, CDRs: ON/OFF)</td>
</tr>
<tr>
<td>10G BER test two mated pair ()</td>
</tr>
<tr>
<td>10G BER test three mated pair ()</td>
</tr>
<tr>
<td>25G BER test one mated pair. (RIN (@25G BW), total jitter and its components - RI/DDL/PJ/DCD/ISI (PRBS11)</td>
</tr>
<tr>
<td>Dust test 10G (BER of the total link, eye diagram (PRBS31), Tx/Rx optical power)</td>
</tr>
<tr>
<td>Dust test 25G (BER of the total link, eye diagram (PRBS31), Tx/Rx optical power)</td>
</tr>
<tr>
<td>Assemble testing report</td>
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</tbody>
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Deliverables

• Quantification of the performance achievable with singlemode expanded beam MT ferrules and silicon-photonics on-board interconnect
• Understanding of system tradeoffs in designing a silicon-photonics based on-board interconnect system
• Identification of component developments needed to fill gaps in the ecosystem of silicon-photonics-based on-board interconnect
• Build confidence for acceleration of the markets for associated silicon photonics transceivers, connector components, and fiber cables
Summary

• Prototype singlemode multifiber expanded beam connectors manufactured by multiple vendors utilizing differing technologies and approaches were tested for performance in front panel and blind mating optical backplane connector configurations

• Concatenated links of one to five mated pairs of connectors showed stable measurements with repeated mating and no detrimental effects on parallel 25Gb/s silicon photonic device links running PRBS32 data patterns

• Further testing on the effects of temperature, debris contamination and cleaning methods are recommended for further learning to build confidence in the technology
Next-- IPSR Phase II: Expanded-beam Module Interface Project

• Phase II of the AIM Photonics / iNEMI Board-Level Interconnect Demonstrator project will consist of specifying, designing, modeling, building and demonstrating a board-level optical interconnect system in which an expanded-beam optical connector interface will be developed for the chip module.

• Given the complexity of the challenge, and the time and cost associated with fabrication of specialized tooling for optical coupling parts, the Phase II effort is subdivided into 2 Sub-phases, I1a and I1b, each lasting approximately one year.

Each Sub-phase will be a separate iNEMI QuickTurn Project
Contact list

• Project Information / Interest in Participation:
  – Terry Smith, 3M, tlsmith@mmm.com
  – Tom Marrapode, Molex, Tom.Marrapode@molex.com

• iNEMI & IPSR Organizations
  – Robert C. Pfahl, - iNEMI, (IPSR) AIM Photonics Academy, bobpfahl@inemi.org
  – Grace O’Malley, iNEMI, graceomally@inemi.org
  – David Godlewski, iNEMI, dgodlewski@inemi.org
  – iNEMI, www.inemi.org
  – IPSR, www.photonicsmanufacturing.org
iNEMI Project

Project Update iNEMI Webinar 6/13/2018